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NATURAL CONCEPTS IN A JUVENILE GORILLA (GORILLA GORILLA GORILLA) AT THREE LEVELS OF ABSTRACTION

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The extent to which nonhumans are able to form conceptual versus perceptual discriminations remains a matter of debate. Among the great apes, only chimpanzees have been tested for conceptual understanding, defined as the ability to form discriminations not based solely on simple perceptual features of stimuli, and to transfer this learning to novel stimuli. In the present investigation, a young captive female gorilla was trained at three levels of abstraction (concrete, intermediate, and abstract) involving sets of photographs representing natural categories (e.g., orangutans vs. humans, primates vs. nonprimate animals, animals vs. foods). Within each level of abstraction, when the gorilla had learned to discriminate positive from negative exemplars in one set of photographs, a novel set was introduced. Transfer was defined in terms of high accuracy during the first two sessions with the new stimuli. The gorilla acquired discriminations at all three levels of abstraction but showed unambiguous transfer only with the concrete and abstract stimulus sets. Detailed analyses of response patterns revealed little evidence of control by simple stimulus features. Acquisition and transfer involving abstract stimulus sets suggest a conceptual basis for gorilla categorization. The gorilla's relatively poor performance with intermediate-level discriminations parallels findings with pigeons, and suggests a need to reconsider the role of perceptual information in discriminations thought to indicate conceptual behavior in nonhumans.

Key words: natural concepts, levels of abstraction, touch screen, gorilla

Pigeons (Herrnstein, 1979; Herrnstein, Loveland, & Cable, 1976) and several monkey species (D'Amato & Van Sant, 1988; Fabre-Thorpe, Richard, & Thorpe, 1998; Fujita, 1987; Phillips, 1996; Shrier & Brady, 1987) have shown some evidence of the acquisition of so-called ''natural concepts.'' For example, nonhuman animals (hereafter, animals) can be trained to select pictures representing a variety of categories, such as trees, humans, and water. However, animals often do not learn the discrimination until hundreds of photographs have been shown, over many hundreds of trials, and have not consistently demonstrated a high degree of transfer to novel stimuli. Transfer is evidenced when subjects' initial performance with novel stimuli is above chance, and is taken as a measure of concept formation because it shows generalization of knowledge about the general category as opposed to memorization of specific exemplars.

Although there are many examples of natural concept formation in birds and nonhuman primates (Brown & Boysen, 2000; Fujita & Matsuzawa, 1986; Herrnstein et al., 1976; Phillips, 1996; Shrier, Angarella, & Povar, 1984; Yoshikubo, 1985), the results have not conclusively eliminated the use of perceptual rather than conceptual processes (D'Amato & Van Sant, 1988; Huber, 1999; Shrier & Brady, 1987). In part, this failure stems from the difficulty in disentangling the role of perceptual and conceptual processing in concept formation. The stimuli presented necessarily convey perceptual information, particularly when one is working with nonverbal subjects and must rely on the use of pictorial stimuli (Huber, 1999). Often, however, one is testing for knowledge of concepts that are defined more generally than by the perceptual details of the training stimuli alone. Therefore it is important to show that subjects can transfer learning to novel exemplars that vary from training stimuli along several dimensions, such as orientation, color, and depth, and that no single feature is sufficient to facilitate transfer on discrimination tasks. Otherwise, the subject may learn not a natural concept, such as ''choose water,'' but rather a perceptually based rule such as ''choose blue.''

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Jitsumori and Matsuzawa (1991) demonstrated that rhesus and Formosan monkeys showed transfer only to full frontal and rear views of humans but not to close-ups of human faces, suggesting that the monkeys did not understand a general concept of "human." This finding suggests that nonhumans may tend to view a stimulus in terms of its specific parts or features, instead of as a more general concept. Such results are consistent with stimulus generalization, which is evidenced when the appropriate response to a stimulus has been learned through extended experience or training and the same response is evoked upon presentation of a novel stimulus that is similar enough to the original stimulus to activate the same pattern of excitation or inhibition. The ability to make a correct response thus does not depend on recognition of a general category but may be automatically invoked by the presence of features that have been associated with reward. To demonstrate that nonhuman species can make use of "true" concepts, they must show immediate transfer to novel members of a category regardless of whether they look like the training stimuli (Huber, 1999).

Fagot and Tomonaga (1999) recently indicated that even chimpanzees, unlike humans, might attend more to local elements than to the global configuration of compound stimuli. Humans in the same investigation were more likely to attend to the global shape of the stimuli, whereas the chimpanzees tended to attend to local elements or individual parts of the compound. Recently, Hopkins and Washburn (2002) presented chimpanzees and rhesus macaques with a sequential matching-to-sample paradigm. Stimuli differed on the basis of their global configuration, local elements, or both. Both species were able to discriminate stimuli on the basis of their global configuration or local elements, but the chimpanzees exhibited a global-to-local processing strategy and the rhesus monkeys exhibited a local-to-global processing strategy. Thus, chimpanzees responded more quickly when required to attend to the global configuration as opposed to the local elements of compound stimuli, whereas macaques exhibited the opposite bias. Taken together, these studies indicate that monkeys are likely to attend to local features and humans are likely to attend to global aspects of stimuli, and the processing of chimpanzees may fall somewhere in between. Thus, it is reasonable to predict that other great ape species may also form abstract general concepts, as opposed to attending to individual features of the stimuli.

Concepts may be formed at various degrees of abstraction, defined in terms of the breadth of the category to be learned (Roberts & Mazmanian, 1988; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). As concepts become more abstract (and thus less concrete), exemplars within the category share fewer features in common. At the concrete level, exemplars may share more readily perceivable attributes such as size, shape, and color, such that members within a concrete category appear similar to each other. For example, "orangutan" is a concrete category. All of its members are large, reddish orange, hairy, have two arms and legs, and so forth. More abstract categories contain members that are perceptually distinct from each other. That is, the features shared by category members may be difficult to discriminate on the basis of sensory properties (Benelli, 1988; Gelman, 1988). For instance, all members of the category "animal" share the ability to breathe and reproduce and consist of the same basic internal organs (Gelman, 1989; Ochiai, 1989), features that cannot be directly perceived, particularly in two-dimensional images of the exemplars, such as might be employed in experimental procedures. In these cases, it is more difficult for individuals to categorize on the basis of single or perceptual features (Astley & Wasserman, 1999). Therefore, at an abstract level, concept learning may be said to rely less on perceptual features and more on conceptual understanding that would enable the individual to combine information about several features into a stable general category representation (Eimas & Quinn, 1994; Spalding & Ross, 2000). Thus, although one would necessarily make use of the information contained in the perceptually presented image, one would also rely on more conceptually based knowledge associated with the visual representation to make inferences about category membership.

Roberts and Mazmanian (1988) examined concept discrimination learning at various levels of abstraction in pigeons, squirrel monkeys, and humans. At the most concrete level, subjects were asked to select photos of kingfisher birds from photographs of various other bird species. This discrimination was deemed concrete because all kingfisher photos shared several readily discernible features (e.g., size, color, and shape) that were not shared by members of the nonreinforced (S−) category. All three species tested easily learned this discrimination. At an intermediate level of abstraction, subjects were asked to select photos of birds from various other animal species. The bird members of the reinforced (S+) set shared several discernible features, but there was more variance between them in terms of features (e.g., color, shape, and size). At the most abstract level, subjects were asked to select animal photos from those of nonanimals. Members of the S+ animal set shared the fewest features in common with each other relative to the other categories, and the features that they did share were less easy to discern visually. The researchers were surprised to discover that pigeons and monkeys learned the most abstract category discrimination more easily than the intermediate discrimination. This finding may have been due to the fact that exemplars from the positive and negative categories in the most abstract discrimination were perceptually more distinct, relative to the intermediate discrimination. For instance, birds may look more like the nonbird animals than animals looked like the nonanimals. In fact, there was some evidence that the intermediate discrimination was easier to learn if nonanimal photos comprised the negative category. These data suggest that pigeons and monkeys were not necessarily operating on the basis of conceptual processing but may have been relying on the perceptual features of the stimuli.

A logical starting point to look for abstract conceptual abilities is in our closest relatives, the great apes. The purpose of the present experiments was to investigate natural concept formation in gorillas because, of the apes, only chimpanzees' knowledge of natural categories has been examined. We wished to extend previous findings to an ape species that is rarely tested for conceptual abilities. Thus, the subject of these experiments was a captive-born experimentally naive juvenile female gorilla. Digitized photographs were presented on a touch-screen computer, using some tasks that were roughly analogous to the tasks presented to Roberts and Mazmanian's (1988) subjects, and intended to represent the same three levels of abstraction. The subject was trained with exemplars from each S+ and S− category until criterion was reached and then was tested for transfer to a novel set of photos representing the same categories.

Examination of errors made by nonhuman subjects often reveals that they attend to irrelevant features. For instance, D'Amato and Van Sant (1988) found that macaques learned to select photos that included humans and to avoid selecting photos that did not include humans, and showed above-chance transfer to novel human-present and human-absent slides. Yet an examination of the subjects' errors revealed that responding was often controlled by patches of red in the photos, regardless of whether humans were present or absent, and human clothing in many of the photos had some red tones. Hence, whether or not the macaques had formed a concept of "human" that matches our own remains in doubt. For "true" concept learning to be in effect, irrelevant features should not gain control of responding. Thus, it is important, when possible, to eliminate the possibility that subjects are using irrelevant aspects of the photos to make the discriminations, either by controlling features of the stimuli that are used or by analyzing subjects' errors. Both approaches were taken in the current work, by varying as many aspects of the photographs belonging to the same categories as possible, and by examining the degree to which these aspects influenced responding to individual photographs.

GENERAL METHOD

Subject

The subject was a 4-year-old captive female western lowland gorilla named Zuri. She had been raised by humans and had not yet been fully integrated into the gorilla group at the Toronto Zoo, so she was housed in relative isolation. She had not previously participated in any research.

Materials

Within each task, each photo set was comprised of 10 reinforced (S+) and 10 nonreinforced (S−) category exemplars. Care was taken so that S+ and S− category exemplars shared similar backgrounds and were matched on as many other features as possible (see the Appendixes). Nearly all of the photos were in color. No photograph appeared in more than one set. Each photograph belonging to a particular set was shown once each session for that discrimination. One set of photos was used for training and was presented until criterion was reached. At that time a set of novel photos was presented as a test of transfer.

As summarized in the Appendixes, all photo sets included some individuals and some groups and a mixture of close-up and long-distance shots, as well as both full and partial body views. Orientation also varied such that the subjects in the photos faced different directions. Animals and humans were of both genders and different ages. Because such factors were varied unsystematically instead of being held constant (as in Brown & Boysen, 2000), the extent to which reliance on perceptual features would aid in performance of the task was presumably minimized, and we were able to look for patterns in the errors and correct choices of the subject.

Procedure

These experiments were conducted while Zuri was housed alone in the Toronto Zoo health unit. The experimenter worked with Zuri for up to 2 hr each day over a 2-week period.

An Apple® touch-screen monitor (13 in.) was placed several inches from the front of Zuri's housing. Zuri had to reach underneath the mesh cage housing to touch the screen. The experiment ran on a Macintosh® PowerBook 5300 computer and was programmed in Filemaker Pro 3 software. Each session consisted of 10 trials that each involved presentation of a pair of photographs, one from the S+ category and one from the S− category. Photographs were presented in a random order and were randomly paired. Presentation was counterbalanced so that the S+ photographs appeared on one side of the screen for half of the trials within each session. The experimenter always was positioned behind the monitor and viewed the subject's response on the laptop monitor and therefore could not direct the subject's gaze to the correct photo or otherwise visually cue the subject.

Touching the S+ photograph was reinforced with a piece of dried fruit or a nut (both highly preferred foods), in unsystematic alternation across trials. Touching the screen registered a choice and cleared the screen. Presentation of the next pair of photos immediately followed reinforcement or selection of the S− stimulus. Zuri completed 1 to 23 sessions per day. The interval between sessions was always at least 2 min. When a mastery criterion of two consecutive sessions at 80% or more correct choices was reached, Zuri was given transfer trials that consisted of novel photographs representing the same category discrimination.

Because Zuri completed many sessions in a single day, it was sometimes necessary to use different sets of photographs within the same testing period to maintain her interest in the task. In Phase 1, for example, sessions of orangutan versus human photos were intermixed with sessions of gorilla versus human photos. In general, across phases, the discriminations were presented sequentially with increasingly abstract category discriminations following the most concrete discriminations. However, Phase 2 began during continued presentation of orangutan versus other primate photos, and the orangutan color test and primate controls were not presented until after Zuri had reached criterion on the most abstract discriminations. She was then re-presented with those stimulus sets on which she had not yet reached criterion (orangutan/other primate second photo set and primate–nonprimate second photo set). The orangutan color test followed completion of the orangutan/other primate discrimination, and the primate controls followed completion of the primate–nonprimate discrimination at the end of the experiment.

Data Analysis

Throughout this study, only the first two sessions with novel photographs were used to indicate transfer. If above-chance performance (≥80%) was not obtained, training continued with a second set of photos until the mastery criterion was reached. Zuri was then given a third set of novel photos to give her another opportunity to show transfer to new stimuli. On a few occasions, even after Zuri had demonstrated transfer, a third set of photos was introduced to corroborate the finding.

To examine the possible role of specific stimulus attributes in guiding discriminations, the photos were coded across several dimensions that could have served as relevant or irrelevant features. These included reinforcement history (species had or had not previously served as S+), presentation history (species had or had not been presented previously), presence of facial features (face visible vs. face not visible), color (color vs. black-and-white photo), relative size of exemplar (10% to 100%, depending on the portion of the photo that was taken up by the image of the category member), orientation (0° to 180° of lateral rotation plus lying on back), number of exemplars present in the photo, part of body in shot (head only, half body, full body, mixed, as in more than one individual, not all shown to the same extent, and partial), age (infant, young adult, old adult, and mixed), and gender (female, male, unknown, and mixed). A summary of the features associated with each set of photos appears in the Appendixes. Two independent observers agreed completely on the coding.

To determine whether transfer could result from attending to a single feature, a univariate analysis of variance was conducted on Zuri's percentage of correct responding for each type of discrimination, with the aforementioned variables included as factors. Only main effects were evaluated in these analyses. All of the coded variables were included in each of these analyses unless otherwise noted, because, although some might not accurately predict membership in the relative categories, the subject may nonetheless be attending to these ''irrelevant'' factors; thus, these factors might account for some errors.

Additional analyses compared the characteristics of photos on which average performance was greater than 80% correct (high-discriminability or HD photos) and photos on which average performance was at or below 50% correct (low-discriminability or LD photos). Independent samples *t* tests were then conducted to determine whether the attributes of the HD photos differed from those of the LD photos, using the coded attributes of the variables described above. A list of the photos on which responding was at or below chance within each set is presented in Table 1.

For all independent samples *t* tests, differences were considered significant based on alpha values of .05. This fairly liberal alpha value (uncorrected for multiple analyses) was adopted to avoid Type II errors in the identification of possible stimulus factors controlling Zuri's choices.

Table 2 presents the reinforced (S+) and nonreinforced (S−) stimulus set descriptions, as well as the results, for each phase of the experiment.

PHASE 1: CONCRETE DISCRIMINATIONS

Four discrimination tasks were considered to be concrete discriminations, because members within the S+ sets all belonged to the same species and therefore shared many features and looked alike.

Gorillas or Orangutans Versus Humans

Five sets of photographs were used in this task. Each set of photographs included 10 photos of humans (S−). Human subjects were of various racial backgrounds but were predominantly Caucasian. Two sets of photos also included 10 gorilla photos (S+) each, and the other three sets included 10 orangutan photos (S+). All of the photographs were in color except for one human, three orangutan, and one gorilla photo that were black and white.

Orangutans Versus Other Primates

Three sets of orangutan (S+)/other primate (S−) photos were used, for a total of 60 photographs. The photos included subjects from various stages of development and of both genders. The photos of other primates included a wide range of primate species including prosimians, both Old and New World monkeys, and the other ape species, including gorillas (see Appendix A).

Orangutan Color Test

In the preceding tests, it was possible for Zuri to learn to select orangutan photos by attending to a single feature: their reddish color. No other variable was constant across all S+ photos and was also rare among S− stimuli. Therefore two sets of photos were presented in which some of the orangutan photos (S+) were color and some were black and white, and the S− photos included only animals that were colored similarly to orang-

Table 1

Photos on which correct responses were at or below chance for each type of discrimination.

Discrimination	Set		Photo	% correct
Gorilla–human	Training	S+	Young dead gorilla	40.0
			Gorilla grooming	50.0
			Adult gorilla	40.0
		S−	Black-and-white woman	40.0
			Experimenter	40.0
			Young woman	40.0
	Transfer	S+	Lowland infant	50.0
			Adult gorilla	50.0
			Mountain group	50.0
		S−	Young girl	50.0
			Human baby	50.0
			Five young children	50.0
Orangutan–human	Training	S−	Black-and-white woman	40.0
			Experimenter	40.0
			Young girl	40.0
	First transfer	S+	Subadult orangutan	50.0
		S−	Young girl	50.0
			Human baby	50.0
			Five young children	50.0
	Second transfer	S+	Mom orangutan in tree	50.0
		S−	Three adult humans	50.0
			Woman and two children	50.0
Orangutan–other	Training	S−	Langur	33.3
			Squirrel monkey	47.1
			Gelada	50.0
			Proboscis	55.6
			Geoffrey marmoset	28.0
		S+	Bornean male	50.0
			Baby on back	55.6
			Baby with twig	55.6
			Large adult male	55.6
			Young orangutan	55.6
			Nursing orangutan	55.6
			Orangutan with dog	28.0
	First transfer	S+	Fat orangutan	52.0
			Two young orangutans	36.0
			Sleeping orangutan	56.0
			Baby with twig	40.0
			Two young orangutan	45.8
			Young in tree	50.0
		S−	Hamadryas baboon	36.0
			Wooly monkey	40.0
			Chimpanzee	48.0
			Chimpanzee	50.0
			Cottontop tamarin	56.0
			Side view macaque	56.0
	Second transfer	S+	Mom all fours	25.0
			Swinging orangutan	50.0
		S−	Gorilla	50.0
			Chimpanzee	50.0
Orangutan color test	Training	S+	Fat male	16.6
			Family in tree	16.6
			Black-and-white baby	33.3
		S−	Reddish lemur	33.3
			Tamarin	33.3
			Lemur	33.3
			Uakari	50.0
			Uakari	50.0

Table 1

(*Continued*)

Discrimination	Set		Photo	% correct
	Transfer	S+	Male side view	50.0
			Black-and-white mom	50.0
			Baby in cage	50.0
		S−	Red panda	50.0
			Red spider monkey	50.0
			Uakari	50.0
Gorilla–other	Training	S+	Adult eating	0.0
			Baby in leaves	37.5
			Side view	14.3
			Young closeup	42.9
			Infant gorilla	50.0
			Silverback	50.0
		S−	Tribal human girl	12.5
			Emperor tamarins	37.5
			Orangutan	50.0
			Chimpanzee	50.0
			Mangabey	50.0
	Transfer	S+	Side view gorilla mom	50.0
Primate–nonprimate	Training	S−	Wolf	8.3
			Cheetah	27.3
		S+	Marmoset	45.5
			Familiar orangutans	50.0
	First transfer	S+	Gorilla	23.8
			Bonobo	40.0
			Familiar male orangutan	33.3
			Chimpanzees	52.4
		S−	Prezwalski horse	38.1
			Dikdiks	42.9
			Wallaby	45.0
			Lion	28.6
			Macaw	52.4
		S+	Tarsier	52.4
	Second transfer	S+	Chimpanzee	33.3
			Celebese macaques	50.0
		S−	Tiger	50.0
Animal–nonanimal	Training	S+	Fish	33.3
		S−	Leaves	45.0
			Zoo exhibit	45.0
	First transfer	S+	Lizard head	50.0
			Rhino from back	50.0
	Second transfer	S+	Crocodile baby	50.0
	Third transfer	S+	Elephants	50.0

utans. If Zuri was responding only on the basis of color by choosing photos in which the subject was reddish orange, she presumably would not show transfer to the black-and-white photos of orangutans and would often incorrectly select the S− exemplars. If, however, she understood that all orangutan photos belonged to the correct category, she should show transfer to these novel sets of control photos.

The first set of S− stimuli consisted only of primates. The second set included two nonprimate species, a red panda and a red squirrel, plus a black-and-white photo of a gorilla (included to determine whether Zuri would incorrectly learn to choose all black-and-white photos) and a photo of a male saki monkey (whose cheek flanges resembled the facial structure of adult male orangutans). This task was presented to Zuri 6 months after completion of the rest of the experiment. She was not initially tested on this task because she had not shown transfer to novel orangutan photos when they were paired with a mixture of other primate species. When these photos were presented again 6 months

Table 2

Sessions required to reach criterion of 80% or better for two consecutive sessions and percentage of correct responding on first two sessions with novel stimuli, for each type of discrimination across each phase.

Phase	S+	S−	Set	Sessions to criterion	Performance on first two sessions: Session 1	Session 2
1	Gorillas	Humans	1	14	50	90
			2	2	90[a]	80[a]
	Orangutans	Humans	1	7	60	60
			2	2	90[a]	80[a]
			3	2	90[a]	80[a]
	Gorillas	Other primates	1	16	60	50
			2	3	70[a]	80[a]
	Orangutans	Other primates	1	19	67	40
			2	25	60[a]	50[a]
			3	3	60[a]	80[a]
	Black-and-white orangutans	Other red primates	1	7	20[a]	40[a]
			2	2	80[a]	90[a]
2	Primates	Nonprimates	1	12	60	70
			2	23	50[a]	40[a]
			3	3	78[a]	89[a]
	Difficult primates	Nonprimates	1	2	80[a]	90[a]
	Faces-only primates	Faces-only nonprimates	1	2	90[a]	80[a]
	Body-only primates	Body-only nonprimates	1	4	90[a]	60[a]
3	Animals	Nonanimals	1	12	60	50
			2	2	80[a]	80[a]
			3	2	90[a]	90[a]
			4	2	89[a]	90[a]
	Foods	Animals	1	8	60	80
			2	7	80[a]	50[a]

[a] Performance on transfer sessions.

later, Zuri reached criterion on the last set, making relevant a test of color as a cue.

Gorillas Versus Other Primates

Zuri was tested on gorillas (S+) versus other primates (S−) as well, because she had no direct experience with orangutans, either live or photographed, and might have more difficulty perceiving the diverse photos as representing a single species, especially given the extreme sexual dimorphism in adult orangutans. These two photo sets were composed in the same manner as were the orangutan/other primate sets, but included all novel photos.

Results

Gorillas Versus Humans

As shown in Table 2, Zuri reached criterion in 14 sessions and showed transfer, performing at 90% and 80% correct on the first and second transfer sessions, respectively. A univariate analysis of variance (ANOVA) (as described above) revealed that none of the coded stimulus features significantly accounted for the variance in Zuri's performance on the gorilla–human photos, highest $F(1, 21) = 2.48$. There was no obvious pattern to Zuri's errors. All but six photographs were responded to correctly most of the time (see Table 1). A series of independent samples t tests determined that HD and LD photos did not vary according to any of the stimulus attributes we had coded, highest $t(35) = -1.47$.

Orangutans Versus Humans

As shown in Table 2, Zuri reached criterion in seven sessions on this discrimination and performed at 80% correct or higher on the first two transfer sessions. There were no immediately obvious patterns in Zuri's errors during this task. A univariate ANOVA (as described above) revealed that only age of the subject in the photographs significantly affected Zuri's performance, $F(4, 27) = 2.83$, $p < .05$. She was more likely to classify adults correctly than she was to classify younger individuals correctly. Independent samples t tests determined that HD and LD photos differed only according to orientation, $t(39) = -3.32$, $p < .01$. The LD photos were always forward-facing orientations, and the HD photos included a mixture of forward and other orientations.

Orangutans Versus Other Primates

As shown in Table 2, Zuri reached criterion after 19 training sessions with the first set of photographs. She did not show transfer to the second set of photos, and she required 25 sessions to reach criterion on this second set when testing was resumed 6 months later. She then reached criterion on a third set of orangutan/other primate photos after only three sessions, although she performed at only 60% on the first session.

A univariate ANOVA was conducted with the same factors as above, except that color was coded as black and white, red or orange, black, brown or gray, light, or mixed for both the t tests and the ANOVA. The only factors that significantly influenced Zuri's performance were whether the species had been previously seen and the number of individuals in the photos, $F(1, 36) = 4.09$ and 4.59, respectively, $p < .05$ in both cases. Surprisingly, she tended to choose photos of species that she had not previously seen more often than those that she had seen before. A series of independent samples t tests determined that HD and LD photos varied according to orientation, $t(36) = 2.14$, $p < .05$. In general, photos presenting the subject from a side view more often belonged to the LD group (nine were responded to poorly and two were responded to accurately). Photos of individuals facing forward belonged equally often to both sets.

Orangutan Color Test

As shown in Table 2, Zuri mastered the first photo set in seven sessions but did not show transfer to the second set. After mastering the second set in two sessions, she showed transfer to the third.

Color was coded as black and white or color. A univariate ANOVA (as described previously) revealed no significant effects for any of the coded stimulus factors, highest $F(2, 20) = 1.43$. Most important, the color of the photograph did not significantly influence Zuri's performance. A series of independent samples t tests determined that HD and LD photos did not vary according to any of the stimulus attributes we had coded, highest $t(30) = -1.28$.

Gorillas Versus Other Primates

As shown in Table 2, Zuri reached criterion after 16 sessions and showed a high degree of transfer to a second set of photos, reaching criterion after only three sessions.

Color was now coded as black and white, red or orange, black, brown or gray, light, or mixed. A univariate ANOVA revealed that none of the coded stimulus factors significantly influenced Zuri's responding. A series of independent samples t tests determined that HD and LD photos did not differ according to any of the stimulus attributes, highest $t(23) = 1.19$.

Discussion

Zuri showed a high degree of transfer to novel photos of both gorillas and orangutans when these photos were contrasted with photos of humans. She was generally not distracted by irrelevant features of the stimuli, such as orientation, size, or gender. It was possible, however, that Zuri discriminated the two sets of exemplars in each case by attending to specific features, rather than by attending to a general concept of "gorilla" or "orangutan." For instance, she may have learned to "choose black face" or "avoid white face." We therefore examined Zuri's performance on photos that deviated from this pattern and that might be expected to cause her difficulty had she been using simple cues. For instance, the transfer set included a photo of an albino gorilla with a pink face. Zuri responded to this photo correctly during both sessions, indicating that she was not responding solely to color of the subjects as a cue to mediate correct performance. Although Zuri accurately selected the photo of the albino gorilla on both of the transfer sessions, the fact remains that gorillas are perceptually distinct from humans, as are orangutans. For this reason, this is considered to be a concrete discrimination, and Zuri's performance does not allow us to distinguish between the use of a perceptual and a conceptual strategy. In the subsequent tasks, it was clearer that Zuri was not attending solely to single features such as color of the animals depicted in the photos.

Zuri required fewer sessions to reach criterion in discriminating orangutans from humans, relative to gorillas from humans, despite the fact that she had never before seen an orangutan. Because she was given gorilla–human and orangutan–human photo sets on alternating days, she might have learned not to "choose orangutan" or "choose gorilla" but to "avoid human." When presented with orangutan photos paired with other primates, Zuri could no longer use an "avoid human" strategy. Her performance did decline on this task. She required more sessions to reach criterion and did not show transfer. Zuri's somewhat erratic performance on the orangutan/other primates discrimination suggested that she may have had difficulty recognizing various orangutans as members of the same species. This finding could be due to the high degree of sexual dimorphism present in orangutans. Adult males appear quite different from subadults, juveniles, infants, and even adult females.

To address this, Zuri was next presented with gorilla/other primate photos, an analogous concrete discrimination but one that might be less ambiguous. She required 16 sessions to reach criterion but did show transfer to novel photos. Furthermore, Zuri was not more likely to select the photos of primates that had previously served as S+ or other primates that most closely resembled those that had previously served as S+. For example, when tested with orangutan/other primate photos, it was expected that she might mistakenly choose photos of gorillas because selection of these had also been previously reinforced, but she did not. These results suggested that Zuri treated each novel discrimination as a new discrimination and was not influenced by prior reinforcement contingencies, a finding that argues against stimulus generalization interpretations.

Zuri did not appear to respond on the basis of a single feature, such as color, that would allow her to make selections accurately. If color was the only cue she used, she would have been expected to select all black primates during the gorilla/other primate discrimination at high rates and to fail to select the photo of the albino gorilla during the gorilla–human discrimination, but she did neither. Furthermore, presenting her with black-and-white photos of orangutans contrasted with reddish orange nonorangutan primates explicitly tested her use of color to select photos of orangutans, and color was not a variable that influenced her responding to these photos.

It was difficult to identify other features that might have served as the basis for discriminating primates in these later tasks, in that stimuli were deliberately chosen that increased the variance between exemplars in a single category and decreased the variance between exemplars between categories. The S− and S+ exemplars were matched on as many features as possible, and the similarities within the S+ set were minimized as much as possible. This was true for all photo sets, so it is also unlikely that the S+ and S− exemplars from the transfer set were more easily discriminated than the exemplars from the training set, thus accounting for the high transfer performance. A summary of the number of photos within each set that exhibited particular patterns of features appears in Appendix A.

PHASE 2: INTERMEDIATE DISCRIMINATIONS

Primates Versus Nonprimates

When Zuri successfully completed the concrete discriminations, she was presented with an intermediate discrimination of primates (S+) versus nonprimate animals (S−). The primate category again included a wide mixture of primate species ranging from prosimians to apes. The nonprimate photos consisted of animals from varying taxa, including mammals, reptiles, insects, birds, and fish. All of the animal photos had similar backgrounds. Appendix B lists the species that appeared in each photo set.

Primate Controls

We wished to investigate further what features enabled Zuri to classify primates into the same category. Was she using facial structure or the entire body structure of various species to categorize them similarly? Quinn and Eimas (1996) demonstrated that human infants use facial but not body-structure information to discriminate between cats and dogs. Zuri was first tested on the stimuli from the three sets of primate–nonprimate photos on which she had most often erred. Zuri participated in this procedure 6 months after she had initially learned the primate discrimination, and this time she was able to reach criterion on the first two sessions. In addition, one photo set of primates (S+) and nonprimates (S−) with only their faces visible and one photo set with only their bodies visible and faces occluded were composed. Transfer was tested to each of these novel photo sets.

Results

As shown in Table 2, Zuri reached criterion with the first photo set after 12 sessions, but did not show transfer. She required 23 sessions to reach criterion with the second set. Although she reached criterion in three sessions with the third set, her performance during the first transfer session (78%) was slightly lower than that required to meet the definition of transfer. This ambiguous outcome was mirrored in Zuri's performance with three sets of control photos. She met the definition of transfer for two sets (difficult primates vs. nonprimates and faces-only primates vs. faces-only nonprimates) but not for a third set (body-only primates vs. body-only nonprimates).

Species was coded as insect, fish, reptile–amphibian, bird, or mammal. An ANOVA on Zuri's performance revealed that only the age of the subjects significantly affected her responding, $F(3, 32) = 4.13$, $p < .05$, even though this was one of the variables that did not distinguish the negative and positive exemplars (see Appendix B). Zuri generally preferred photos of other young animals so that she was correct if the primate photo was of a young animal but incorrect if the nonprimate photo was of a young animal.

A series of independent samples t tests determined that HD and LD photos differed according to species, $t(38) = 2.33$, $p = .01$, and the presence of facial features, $t(38) = 1.84$, $p < .05$. All of the LD photos were of mammals except for one photo of a macaw, whereas the HD photos included a mixture of species. In addition, all of the LD photos included facial features, but this was not always the case for HD photos.

Discussion

Zuri seemed to have greater difficulty with the intermediate discriminations relative to the more concrete discriminations. The one variable found to significantly influence responding during this phase was the age of the subjects of the photos, even though this attribute did not reliably differentiate the S+ and S− exemplars. Zuri's tendency to select photos of younger animals apparently interfered with her performance on this task.

Zuri was not more likely to select photos of species that had been previously seen or served as S+, indicating that she was not simply selecting those photos that most closely perceptually approximated stimuli that had previously served as S+. In fact, she selected photos of unusual-looking novel primate species (e.g., an indri, which looked more bear-like than monkey-like to human observers) at least as reliably as she selected photos of species that had previously been seen and served as S+ stimuli. Although it is probably true that novel primate photos were perceptually more similar to previous S+ primate photos than were the novel nonprimate S− photos, a stimulus generalization account would predict that Zuri would most often select photos of species that had previously served as S+ or that most closely resembled those species. This apparently was not the case. The photos that she chose most often, such as one of a sifaka, did not share more features in common with gorillas or orangutans than, for example, photos of chimpanzees that she did not select reliably. These findings mirror those of Phase 1, in which Zuri was accurate on novel photos that looked similar to previous S+ stimuli as well as on novel, perceptually dissimilar stimuli.

PHASE 3: ABSTRACT DISCRIMINATIONS

Animals Versus Nonanimals

Zuri was next tested on a series of animal versus nonanimal discriminations. In the first two sets of photos, the S+ stimuli consisted of a broad range of animal species in a variety of positions and the S− stimuli consisted mainly of landscapes with neutral backgrounds. In the third and fourth sets, the S− stimuli consisted of a mixture of inanimate objects and neutral backgrounds. Pilot work with orangutans in our laboratory suggested that these latter sets were more difficult to discriminate.

Foods Versus Animals

Zuri might perform well on the animal–nonanimal discrimination simply by continuing to choose photos most similar to those that had previously served as S+. Thus, stimulus generalization could yield high levels of initial performance on the animal–nonanimal task. In addition, the animal photos may have comprised a more homogeneous set, relative to the nonanimal photos, in that the former included members of a single category (animals) and the latter included exemplars that did not belong to a single coherent category (objects, trees, water, cages, etc.). Therefore, Zuri was also tested on an abstract discrimination task in which the S+ stimuli were perceptually dissimilar to photos that had previously served as S+ stimuli and were also homogenous in the sense that they belonged to a coherent category (fruits and vegetables). Foods also may be considered an abstract category because they do not necessarily look like other members of their class, but are classified according to their function. Items belong to the category "food" because they are edible, not because they are things that look alike (Bovet & Vauclair, 2001). Two sets of photos were created: Each consisted of 10 novel photos of various animals (S−), including some species that had been previously seen and some that had not. As before, the animal photo set included species from diverse taxa. Each photo set also included 10 photos of various fruits and vegetables (S+), none of which had been presented previously, although Zuri was familiar with all of the foods presented.

Results

Animals Versus Nonanimals

As shown in Table 2, Zuri reached criterion after 12 sessions on the first set of photos and showed transfer on the three subsequent sets of animal–nonanimal photos. The features of the S− stimuli were not subjected to an ANOVA because we were uncertain how to code nebulous stimuli such as neutral backgrounds. A univariate ANOVA of Zuri's scores showed that none of the factors influenced her responding on the animal photos, highest $F(4, 14) = 1.51$. Neither color nor gender was included as a variable in this analysis, because color was not predictive and gender was usually unknown. Species was coded as insect, fish, reptile–amphibian, bird, or mammal. The stimuli were not divided into HD and LD photos because Zuri's accuracy was low on only five photos. These photos did not stand out according to their values on any of the attributes that might have influenced Zuri's performance (see Table 1).

Foods Versus Animals

Zuri reached criterion in fewer sessions than that required to learn the animal–nonanimal discrimination and performed at 80% on the first transfer session (Table 2). The features of the S+ set were not analyzed in an ANOVA because it was difficult to identify features that might predict performance. An ANOVA on Zuri's scores for the animal photos (same factors as for the animal–nonanimal discrimination) revealed no significant effects, highest $F(2, 2) = 4.28$. There were only two animal photos on which Zuri achieved less than chance performance (Table 1) so the stimuli were not divided into HD and LD photos.

Discussion

It appeared that the more abstract concept discrimination of animals versus nonanimals was easier for Zuri to learn than the intermediate discrimination of primates versus nonprimate animals, as evidenced by fewer sessions required to reach criterion and by transfer to the first set of novel photos. Zuri's performance was not influenced by whether or not the animal photos displayed facial features, were of a more familiar species (such as a mammal), or showed species that previously had been presented or served as S+. The latter findings indicated that Zuri might not have been relying on perceived similarity to previous S+ stimuli. That Zuri transferred learning to diverse novel stimuli that shared few obvious perceptual features with the previous S+ exemplars argues against stimulus generalization accounts. Although novel animal photos usually were more similar to previous S+ animal species than were novel nonanimal S− photos, this was not always the case. For instance, a photo of a worm lizard was visibly similar to a photo of a stick. A photo of clay elephants and two photos of horse and rider statues may have appeared more similar to some of the animal photos than to the other nonanimal photos, yet responding to these photos was no less accurate than performance on what might be considered "easier to discriminate" photos.

One might argue that Zuri performed well on the animal–nonanimal discrimination not because she made use of an abstract concept for "animal" but because animal photos in general were perceived as being more perceptually similar to previous S+ stimuli in other phases of the experiment. As evidence against this argument, Zuri did not initially perform at 80% or higher on the very first animal–nonanimal session. Furthermore, the previous S− animals were most similar to the animals presented in the current task. As a further control against generalization, Zuri was also tested on a discrimination in which she was required to select photos of a novel category (foods that included diverse exemplars), and she learned to select foods in even fewer sessions than she learned to select animals. In addition, she did not show a marked preference for selecting the animal photos on the first sessions of the new test, indicating that she was not biased to select the most familiar photos initially. Her performance suggested that she was not reliant solely on learning associations between features and past reinforcement histories.

It is possible that Zuri learned to select food photos not by learning or using a concept for "foods" but by learning to avoid the previously learned category "animal." On the first set of photos, she was more accurate at avoiding photos of nonmammal animals, which would appear less similar to those that had previously served as S+. By the second set of photos, she was just as accurate at avoiding less typical or familiar animal species. To use the strategy of avoiding S− photos, Zuri would have to either make use of a concept "animal" or reverse the direction of control that prior reinforcement contingencies may have had on her behavior. If reverse discrimination were operating in this task, she might have more accurately avoided selecting photos most similar to previous S+ exemplars, such as primates, which was not the case.

GENERAL DISCUSSION

Zuri learned the concrete and abstract discriminations in few sessions and with a high degree of transfer. She seemed to have the most difficulty with the intermediate discrimination. This pattern parallels the results of Roberts and Mazmanian (1988), who found that squirrel monkeys and pigeons learned an abstract discrimination more readily than an intermediate abstraction. Both sets of findings call into question the usefulness of drawing distinctions between various levels of abstraction in concept formation. Although research with humans has supported this functional distinction (Rosch et al., 1976), research with nonhumans has yet to do so. At least with natural categories, it appears that a more useful distinction may be one in which the amount of overlap of features both between and within categories dictates the ease of categorization. Indeed, it seems unlikely that levels of abstraction could be manipulated independently of the variance in feature overlap across levels. Therefore, it may be useful to define abstractness in terms of both the breadth of the category and the degree to which features overlap between and within categories.

Abstract categories are broader and include members that share fewer perceptual features than less abstract categories. In Rosch's view it is at the intermediate or basic level that category distinctiveness is maximized, because exemplars share many features in common within the category and few features in common with members of other categories (Rosch et al., 1976). In the present study, however, the intermediate level of abstraction contrasted two categories in which the S+ (primates) exemplars shared several features with S− exemplars (nonprimate animals). Thus, although within-category similarity may have contributed to the distinctiveness of the intermediate S+ category, the overlap in features between S+ and S− categories may have led to an increased difficulty with this discrimination (see also Roberts & Mazmanian, 1988). Although the most abstract categories included exemplars that shared few features within the category, the amount of feature overlap between S+ and S− categories was less than for the intermediate discriminations. It seems likely, therefore, that within-class and between-class similarities interact to determine the relative difficulty of discriminations at various levels of abstraction.

Categorization by nonhumans may reflect

the degree of feature overlap in experimental stimuli rather than the subjects' general knowledge of natural categories. Such categorization thus may not correspond to distinctions based on a general category of ''breadth'' or the degree to which category members are defined by nonperceptual features. A human-defined concept may be assumed to incorporate all possible perceptual and nonperceptual qualities that indicate category membership based on the individual's extensive prior experience. It is difficult to determine whether categorization by nonhumans reflects the same degree of generalized category knowledge. The present data suggest otherwise.

Although the present study does not allow us to determine conclusively the extent to which Zuri based her categorizations on general category knowledge or on observable feature overlap within the stimulus sets, certain aspects of the findings argue against simple similarity-based accounts of categorization. Similarity theories suppose that novel items are assigned category membership according to their resemblance to known category members. Although members of the novel S+ set shared more features with the learned S+ set than did members of the novel S− set, Zuri did not exclusively select the members of the novel sets that most resembled the training sets on the basis of shared physical features. Therefore her successful transfer is difficult to account for with stimulus generalization or similarity judgment interpretations.

Particularly striking is the high degree of transfer shown by the gorilla in some phases of this study. This degree of transfer has not previously been demonstrated in other nonhuman species. Although S+ selections were reinforced on transfer trials, Zuri's performance on these trials almost always exceeded that on the first sessions with training stimuli, implying that some transfer of prior learning had occurred. On all three of the transfer tests with the most abstract discrimination, Zuri achieved at least 80% correct choices in the first session. This was achieved despite the fact that the novel photographs depicted different animal species than those shown in the original training stimuli. Similarly, the primate and nonprimate photos shown in the various sets of intermediate photos were of different species in each set.

Prototype theories hold that performance should be most accurate for the most typical members of a category, that is, those that share the greatest ''family resemblance'' (Hampton, 1998; Rosch et al., 1976). This model does not provide a likely account of Zuri's performance on the abstract discriminations because several of the primate and animal photos were atypical and shared few features with the most commonly shown photos (e.g., marmosets, indri, and tarsiers in the former category and fish and butterflies in the latter). To make the animal–nonanimal discrimination particularly difficult, photographs of animal statues and sculptures and other objects with possible face-like features (e.g., the headlights of a car) were included. Yet Zuri's performance on transfer tests was uniformly good.

The high degree of transfer in the present investigation suggests that Zuri did not memorize individual photographs and did not perform on the basis of single perceptual features. Although analyses supported the claim that she was not relying on the use of single features, it is possible that she relied on the presence or absence of combinations of features to aid her in the tasks. The present data neither verify nor rule out this possibility. Moreover, it is not clear that a strategy of attending to a combination of several rules or features is incompatible with the way that ''true'' concepts are formed. For a category to be conceptually versus perceptually based, an individual must ''see through the natural variation among exemplars of species'' to form a stable general category (Eimas & Quinn, 1994, p. 915). According to Spalding and Ross (2000), the coherence of a category may partially depend on more abstract features that ''can link together observable features that might otherwise seem to have little similarity'' (p. 439). Therefore, the recognition of observable features is necessary but not sufficient to determine category membership. One must understand how the concept coheres, which involves a conceptual analysis of the total features available for observation.

We acknowledge that the ease with which Zuri learned the most abstract discrimination was partially due to a generic ''learning to learn'' phenomenon, because this was the last discrimination tested. Zuri did require fewer sessions to learn to choose animals and foods than she required on more concrete discriminations. Yet her relative difficulty with the intermediate discriminations argues against an account based solely on accumulated experimental experience.

It appears that concept formation by gorillas may not be limited solely to the perception of physical similarities between the stimuli. The current results suggest a conceptual basis for categorization. It is sometimes assumed that gorillas do not share the more complex cognitive abilities evidenced by their relatives, the chimpanzees (Gomez, 1999; Swartz, Sarauw, & Evans, 1999). Gorilla cognition, however, has been studied infrequently, and it is hoped that the present investigation will encourage more research in this area.

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APPENDIX A

Phase 1: Number of photos per set exhibiting various features for concrete discriminations.

	Gorilla–human				Orangutan–human						Orangutan–other red			
	Set 1		Set 2		Set 1		Set 2		Set 3		Set 1		Set 2	
	S+	S−	S+	S−	S+	S−	S+	S−	S+	S−	S+	S−	S+	S−
Previously reinforced	0	0	10	0	0	0	10	0	10	0	10	0	10	1
Previously presented	0	0	10	10	0	10	10	10	10	10	10	7	10	6
Face present	10	10	10	10	10	10	10	10	9	10	10	10	10	9
Gender														
Female	2	8	0	7	4	8	8	7	8	8	0	0	2	0
Male	1	2	3	1	4	2	2	1	2	2	3	0	3	2
Unknown	7	0	5	0	2	0	0	0	0	0	4	10	3	7
Mixed	0	0	2	2	0	0	0	2	0	0	3	0	2	1
Color														
Yes	10	9	10	10	7	9	10	10	10	10	6	10	5	9
Red														
Black														
Brown														
Light														
Black and white														
Mixed														
Number of individuals														
1	9	8	8	7	7	8	7	7	7	5	7	10	7	9
2	0	2	1	2	3	2	2	2	3	2	3	0	3	1
3	1	0	1	1	0	0	1	1	0	3	0	0	0	0
Body in shot														
Head	4	2	0	2	4	2	5	2	3	3	2	3	1	1
Full body	5	4	2	4	3	4	4	4	6	3	5	5	6	6
Half body	1	4	8	4	3	4	1	4	1	4	3	2	3	3
Age														
Infant	1	3	3	1	2	3	3	1	1	1	2	0	2	0
Young	3	1	1	2	1	1	3	2	5	1	2	1	2	1
Adult	5	6	4	6	5	6	2	6	1	5	2	9	4	8
Old	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Mixed	1	0	2	1	2	0	2	1	3	2	3	0	2	1
Size														
10%	0	0	0	0	1	0	0	0	0	0	0	0	0	1
25%	0	1	1	0	1	1	1	0	0	0	2	1	0	1
50%	2	4	2	6	0	4	3	6	1	2	1	3	2	3
75%	7	5	7	4	6	5	5	4	6	8	5	5	7	4
100%	1	0	0	0	2	0	1	0	3	0	2	1	1	1
Species														
Prosimian											3		1	
Old World											2		2	
New World											5		4	
Ape											0		1	
Nonprimate													2	
Orientation														
Forward	5	8	8	10	5	8	4	10	6	10	8	8	8	4
Half side	3	1	2	0	1	1	1	0	2	0	1	2	0	1
Side	0	1	0	0	4	1	5	0	2	0	1	0	2	5
Back	1	0	0	0	0	0	0	0	0	0	0	0	0	0
On back	1	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX A

(*Extended*)

Gorilla–other				Orangutan–other					
Set 1		Set 2		Set 1		Set 2		Set 3	
S+	S−	S+	S−	S+	S−	S+	S−	S+	S−
10	1	10	1	10	1	10	0	10	1
10	4	10	7	10	1	10	2	10	3
9	10	10	10	10	10	10	10	9	10
0	0	0	1	0	0	2	0	0	0
2	1	1	2	3	2	1	2	1	1
6	8	5	6	6	7	6	8	7	7
2	1	4	1	1	1	1	0	2	2
0	1	0	1	10	0	10	1	10	1
10	4	10	2	0	4	0	3	0	2
0	3	0	6	0	5	0	3	0	5
0	2	0	1	0	0	0	1	0	1
0	0	0	0	0	1	0	1	0	0
0	0	0	0	0	0	0	1	0	1
8	9	6	9	9	9	6	10	8	7
2	1	3	0	1	1	4	0	2	2
0	0	1	1	0	0	0	0	0	1
1	3	3	2	6	3	6	5	2	3
5	7	4	7	3	5	2	4	7	4
4	0	3	1	1	2	2	1	1	3
1	0	0	0	3	0	3	0	1	0
4	2	1	1	3	1	2	3	6	2
3	7	5	8	3	9	3	7	1	5
0	0	0	0	0	0	0	0	0	0
2	1	4	1	1	0	1	0	2	3
0	0	0	0	0	0	0	0	0	0
2	1	0	3	0	0	0	0	2	0
3	5	3	3	0	4	1	1	4	0
4	4	6	4	7	5	6	7	2	9
1	0	1	0	3	1	3	2	2	1
	3		2		1		0		0
	1		2		2		3		2
	3		2		3		5		5
	3		4		4		2		3
4	5	6	7	6	2	5	5	5	7
3	2	0	1	3	6	2	3	2	1
2	3	3	1	1	2	2	2	3	1
1	0	0	0	0	0	0	0	0	1
0	0	1	1	0	0	1	0	0	0

APPENDIX B

Phase 2: Number of photos per set exhibiting various features for the intermediate primate–nonprimate discrimination.

	Set 1		Set 2		Set 3	
	S+	S−	S+	S−	S+	S−
Previously reinforced	3	0	5	0	5	0
Previously presented	9	0	6	0	8	2
Face present	10	9	10	10	10	6
Gender						
Female	1	1	0	1	1	0
Male	0	0	3	1	0	0
Unknown	7	9	6	7	7	10
Mixed	2	0	1	1	2	0
Color						
Red	1	0	1	0	1	1
Black	3	0	4	1	4	0
Brown	5	5	4	4	4	7
Light	0	1	1	4	0	0
Black and white	1	2	0	0	0	2
Mixed	0	2	0	1	1	0
Number of individuals						
1	7	8	9	7	5	8
2	3	1	1	3	4	1
3	0	1	0	0	1	1
Body in shot						
Head	6	0	1	1	0	1
Full body	1	7	6	7	6	8
Half body	3	3	3	2	4	1
Age						
Infant	1	0	0	0	2	0
Young	0	0	1	0	2	1
Adult	6	10	8	9	4	9
Old	0	0	0	0	0	0
Mixed	3	0	1	1	2	0
Size						
10%	0	0	0	0	0	1
25%	0	0	0	1	0	0
50%	1	6	4	4	4	3
75%	7	4	6	5	5	6
100%	2	0	0	0	1	0
Species						
Prosimian	0		2		1	
Old World	3		2		1	
New World	2		1		3	
Ape	5		5		5	
Insect		1		0		0
Fish		0		0		1
Reptile		1		1		1
Bird		2		2		2
Mammal		6		7		6
Orientation						
Forward	8	4	5	5	7	4
Half side	0	0	1	1	2	1
Side	1	6	3	4	0	4
Back	0	0	1	0	0	0
On back	1	0	0	0	1	1

APPENDIX C

Phase 3: Number of photos per set exhibiting various features for abstract discriminations.

	Animals–nonanimals								Foods–animals			
	Set 1		Set 2		Set 3		Set 4		Set 1		Set 2	
	S+	S−	S+	S−	S+	S−	S+	S−	S+	S−	S+	S−
Previously reinforced	3	0	1	0	1	0	2	0	0	2	4	4
Previously presented	3	0	3	10	6	1	4	1	0	3	4	6
Face present	6	0	6	1	5	2	10	1		7		6
Color												
Yes	10	10	10	10	10	10	10	10				
Red									2		2	
Orange									4		4	
Green									3		3	
Brown									0		0	
White									1		1	
Number of individuals												
1	8		7		7		7		7	8	3	8
2	2		2		2		2		1	0	1	1
3 or more	0		1		1		1		2	2	6	1
Body in shot												
Head	2		2		1		1			2		0
Full body	7		8		8		8			4		9
Half body	1		0		1		1			4		1
Age												
Infant	0		0		1		3			0		0
Young	2		3		1		1			4		5
Adult	8		7		5		4			4		5
Old	0		0		0		0			0		0
Mixed	0		0		3		2			2		0
Size												
10%	1	1	1	0	2	1	0	0	0	0	0	0
25%	4	1	3	2	1	2	2	1	2	1	2	1
50%	3	2	1	4	5	3	8	5	7	6	5	6
75%	2	4	5	1	2	3	0	2	1	3	3	3
100%	0	2	0	3	0	1	0	2	0	0	0	0
Shape												
Round									5		5	
Long									2		2	
Other									3		3	
Species												
Insect	2		1		0		1			1		1
Fish	1		1		0		0			2		1
Reptile	1		2		2		2			1		1
Bird	1		1		1		2			1		2
Mammal	5		5		7		5			5		5
Orientation												
Forward	4		5		3		5			4		3
Half side	0		0		1		0			1		1
Side	5		4		4		4			5		6
Back	0		1		1		0			0		0
On back	1		0		1		1			0		0